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REPORT ON THE THIRD UNITED NATIONS TRAINING COURSE ON REMOTE-SENSING EDUCATION FOR EDUCATORS, HELD IN COOPERATION WITH THE GOVERNMENT OF SWEDEN

(Stockholm and Kiruna, Sweden, 3 May-4 June 1993)

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INTRODUCTION

A. Background and objectives

1. At its thirty-seventh session, the General Assembly adopted resolution 37/90 of 10 December 1982, in which it endorsed the recommendation of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) that the United Nations Programme on Space Applications should promote the growth of indigenous nuclei and an autonomous technological base in space technology in developing countries.

2. The Committee on the Peaceful Uses of Outer Space, at its thirty-fifth session in June 1992, endorsed the activities of the United Nations Programme on Space Applications for 1993 as proposed by the Expert on Space Applications and as recommended by its Scientific and Technical Subcommittee at its twenty-eighth session. Subsequently, the General Assembly, by its resolution 47/67 of 14 December 1992, endorsed the activities of the Programme on Space Applications for 1993.

3. In response to Assembly resolution 46/45 and in accordance with the UNISPACE 82 recommendations, the Programme on Space Applications included, as one of its 1993 activities, the organization of a training course on remote-sensing education for educators.

4. The Third United Nations International Training Course on Remote-Sensing Education for Educators was organized in cooperation with the Government of Sweden through the Swedish Agency for International Technical and Economic Cooperation (BITS) and hosted by Stockholm University and the Swedish Space Corporation (SSC Satellitbild) for the benefit of developing countries.

5. The main objectives of the course were to provide educational and practical experience to participants of current and future remote-sensing systems, including the acquisition, processing, interpretation, applications and archiving of the data generated by such systems, as well as to equip them with the ability to introduce elements of the technology, as appropriate, in the educational curricula in their universities and institutes.

6. The participants expressed their appreciation to the United Nations and the Government of Sweden for organizing and hosting the course, for their financial assistance and for the technical quality of the course. Participants will report to the appropriate authorities in their own countries.

B. Organization of the course

7. The course was held at Stockholm and Kiruna from 3 May to 4 June 1993. Welcoming and keynote addresses were given by Mr. S. Pettersson of BITS, on behalf of the Government of Sweden and the Expert on Space Applications from the United Nations Office for Outer Space Affairs. The programme of the course (contained in the annex) was designed jointly by the United Nations Office for Outer Space Affairs, Stockholm University and SSC Satellitbild.

8. Participating in the course were 26 persons from Bangladesh, Bolivia, Chile, Costa Rica, Ecuador, Federal States of Micronesia, Ghana, Jordan, Kenya, Madagascar, Malawi, Malaysia, Mauritius, Nepal, Nigeria, Sri Lanka, Thailand, Uganda, Uruguay, Venezuela, Viet Nam and Zimbabwe.

9. Funds allocated by the United Nations were used to defray the costs of international air travel for 12 participants. The Government of Sweden provided room and board, local transportation and pocket money for all the participants, as well as international travel expenses for 14 participants.

10. The presentations at the course provided participants with a basic understanding of the development and use of remote-sensing technology in natural-resource management and environmental assessment; they were also aimed at equipping them with the ability to serve as a focal point in their own countries and to introduce elements of the technology, as appropriate, into the educational curricula in their universities and educational institutions.

11. A number of lecturers and participants made presentations, including case-studies of projects or programmes in which they were involved conducted in countries of Africa, Asia and Latin America as well as remote-sensing research and training applications in developing countries.

12. Some of the presentations clearly demonstrated that the use of remote-sensing techniques had an impact on decision- and policy-making. Other presentations in which participants used data and satellite imagery from their own countries, provided an overview of remote-sensing applications with an emphasis on case-studies: principles of visual and digital image analysis; and use of Geographic Information Systems (GIS) in different fields of applications.

13. Numerous practical exercises were organized in order to provide the participants with the opportunity for hands-on training in the visual interpretation of remote-sensing data. The course was supplemented by on-site visits to the SSC Satellitbild and European Space Agency (ESA) ground stations, and SSC facilities and laboratories at Satellitbild, Kiruna.

I. SUMMARY OF THE COURSE

A. Remote sensing and global change

14. Advances in measurement technology, particularly satellite-borne remote sensing, allow global monitoring of the environment. New generations of computers have increased the capability to synthesize data sets and to develop increasingly comprehensive numerical models. These tools, coupled with the growing understanding of the components of the Earth system, the atmosphere, oceans, soil and solid earth, and the physical, chemical and biological processes that link them, permit an integrated and interdisciplinary approach to Earth-system studies.

15. Traditionally, monitoring environmental changes is done either by ground surveys or aerial photo-interpretation and these changes are normally detected by a manual comparison of a single-data analysis. For large areas, however, both ground surveys and aerial photo-interpretation methods are impractical due to the large amount of data to be collected and processed, and to improper data handling. Remote sensing, with its big area coverage and short repetitive cycle of capabilities, offers a new and effective alternative. In addition, the digital nature of the data collected makes computer processing possible, which is an advantage in handling a large volume of data.

16. Throughout the years, various methods for detecting environmental changes using remote-sensing techniques have been developed and successfully tested. Space technology has become operational and is being used widely in many countries for resource management and environmental applications. Various case-studies and projects have shown that remote sensing contributes significantly to economic and social development and to an understanding of global change. Currently, all parts of the world are being monitored by Earth Observation Systems (EOS). As the data sets obtained by such sensor systems may represent the only reliable information on a given country, such information is an indispensable element in developing environmental models and data-management systems for the country in question. These models and systems are crucial to understanding and safeguarding the environment as well as to ensuring a more effective management of natural resources at both national and global levels.

17. The latest contribution to the observation of the Earth from space is the microwave-sensor system. This system can function in the dark and can penetrate rain and clouds, thus enhancing the possibilities of obtaining information from cloud-covered areas. Examples of space systems are the European Remote Sensing Satellite (ERS) of ESA, the Japanese Earth Resources Satellite (JERS) and the forthcoming RADARSAT of Canada. Observation of the Earth from space will not only continue but also will be intensified.

18. Remote sensing technology is a multidisciplinary tool. It has many proven applications, particularly in natural-resources management, environmental assessment, disaster mitigation, search-and-rescue missions and the monitoring of drug-related plants. Information obtained from data acquired by EOS can be used as a basis for decision-making as well as a means for monitoring the outcome of decisions. It can provide opportunities for a country to tailor its development activities to its resource base. Such information can also provide a country with the opportunity to enter into mature mutually beneficial resource-exploitation relationships, particularly with other countries. Because observation of the Earth from space can be used for crop forecasting in particular, it provides opportunities for economic bargaining and food-security management.

19. The availability of such data will assist the international community to gain a better understanding of how to safeguard the global environment as well as to ensure a more efficient management and productive harnessing of the natural resources of the planet. Major global programmes such as the International Geosphere-Biosphere Programme (IGBP) and Mission to Planet Earth will contribute to the understanding of global change. However, a prerequisite for the effective participation of all countries in international programmes as well as in national and regional projects is an adequate and long-term commitment to and investment in the development of skills and knowledge in the discipline at the local level.

B. Limitations and potential in developing countries

20. During the initial phases of satellite remote sensing it was postulated, especially within the academic community, that the large quantities of data produced by the satellite sensors would call for a computerized approach to both the analysis of data and the production of thematic maps. Especially in the developing world, satellite remote sensing seemed to represent a short-cut to creating accurate and updated inventories of natural resources and environmental monitoring. Centres for digital data and image analysis were established in many countries, often tied to national mapping agencies, with the aim of supporting national natural-resources inventories.

21. Analysis of a number of applied projects, however, revealed only a limited advancement of the digital-image interpretation technique and associated production of thematic maps. The reason was not the technology as such, but the complexity of the object under study. Classification of data, application of statistical methods and perhaps a new colouring of the satellite scene cannot produce a true and reliable thematic map, in spite of the fact that one of the popular satellite sensors is called the "Thematic Mapper" (TM). In the best of cases, computer manipulation can enhance disparate spectral signatures in the satellite image in order to help the analyst find and interpret what has been recorded by the sensor system. Other image properties that help to detect and identify different features, such as tonal change and spatial arrangement, are seldom taken into account.

22. One major factor behind this limited practical use may be a lack of balance between the push for computer-based, high-tech approaches and more appropriate low-tech methods. In a regional or national inventory, the digital approach can hardly be applied for thematic map production as the environmental variation calls for a constantly renewed calibration of field data, within and between the satellite scenes, as well as between registrations from different seasons. It should be realized that the profession of image interpretation expert does not exist, rather there are experts on different subjects that are also good at image interpretation.

23. The over-emphasis on computer-based handling of satellite data and the concentration of all resources and competence at single, national centres are likely to hinder and seriously delay the vast amount of development work that is necessary to find suitable methods of applying a practical application of the technology. The analysis of satellite data is a highly sophisticated technology that requires large and advanced computer resources. As long as such attitudes prevail in national centres, it is unlikely that the application of satellite information will be transferred from the satellite data laboratory to users at local levels.

24. Hopefully therefore, development of satellite data will follow paths similar to the development of computers. At the advent of computers only a few computer centres existed, which were managed by highly qualified technical specialists; currently personal computers have become useful everyday tools for almost everyone in the industrialized world.

25. To make effective and rewarding use of satellite remote sensing in a developing country in the near future, methods should be introduced and applied that: (a) can have an immediate impact; (b) become operational rapidly; (c) require only a short period of training; (d) require only limited investment; and (e) can be applied not only on a central level but also regionally or even locally.

26. In the future, satellite data will be distributed in formats and on media that can be read and analysed by low-cost personal computers at regional and local levels, i.e. where most of the practical work and field inventories are made. At present, however, satellite data can easily be distributed as images for use at those levels as it is possible to fulfil many of the requirements listed above if much the same technique and instrumentation that is used for studies of aerial photographs is applied also for the analysis of satellite images.

27. As aerial photography has been used in all developing countries for a long time for topographic mapping, land-use and soil conservation planning etc., there exists a local competence in its various techniques. Most authorities and institutions working with aerial photographs are usually well-equipped with viewing equipment, such as stereoscopes and stereo plotters, and are therefore also well-suited for study of satellite images. If necessary, the satellite data vendors can also tailor images to fulfil the demands of the client, but leave the image interpretation itself to the real experts, the end-users.

28. The training needed for satellite image analysis is mainly to familiarize local staff who have a basic degree in their field of expertise with the new types of image the satellite systems provide. Such people are usually eager to absorb and utilize relevant parts of the new technology in order to solve problems in their work. They are familiar with the region they are working in, its topography, geology, land-use pattern, cultivation practices etc., all factors that will be of great importance during the analysis of satellite images. This experience equips them with a new dimension in planning and enables staff at the district, regional or central level to identify problems and potential, and to reach their own decisions on the necessary action to be taken.

29. Past experience of applied satellite remote sensing in developing countries has so far confirmed that the visual interpretation of standard or enhanced image products is the most rewarding path to follow if the intention is to obtain appropriate results by rapidly utilizing the local expertise involved in practical project work.

C. An approach to an applied remote-sensing training strategy in a developing country

30. Up-to-date, reliable and readily renewable information on land, in the broadest sense, is a prerequisite for the effective planning and administration of natural and human resources. There is an increasing awareness in developing countries of the important role that remote-sensing techniques in the form of aerial photography and satellite imagery will play in this context. The data that can be extracted from remote-

sensing imagery, using a wide range of techniques of different levels of sophistication, is multisectoral and can be used for land-use planning and environmental protection, forestry and agriculture, for geological- and mineral-exploration purposes, for water-resources inventories, for communication, for mapping and for environmental monitoring.

31. In most countries, the need for this technology is well understood and demands for its further implementation are growing. Considerable investment has been made in aerial photography during the past few decades and it can be anticipated that full coverage by satellite imagery of a national territory has been or will be acquired. The major constraints on a wider and more efficient use of remote-sensing techniques are: (a) the lack of knowledge of the realistic potential of these techniques at the decision-making level; (b) the limited number of trained specialists; and (c) the lack of trained technicians at the local level.

32. There is a need for a three-level training programme aimed at the following groups: (a) managers: heads of agencies, heads of departments and decision makers, which should include also participants from non-technical groups; (b) specialists who have already worked with remote-sensing techniques and who have a basic knowledge of the scientific background of this technology; and (c) technicians, with emphasis on local-level staff. The latter group has usually a very limited knowledge of remote sensing but can be expected to become the most active users of the technique.

33. Three packages can be envisaged, tailored to meet the needs of the three target groups. It will be necessary to prepare exhibition materials, manuals and compendiums, and audio-visual materials.

34. The course for managers should comprise an overview of the remote-sensing concept and of remote-sensing techniques and a presentation of current applications and future possibilities. Concrete examples of applications in the country concerned should be given together with general cost-benefit data. A question-and-answer technique should be encouraged. The exhibition will be a valuable presentation tool. Other audio-video possibilities should be considered.

35. The course for the specialists should be aimed at broadening and deepening their knowledge of remote sensing beyond the current national level of technology towards more efficient image-analysis systems. There should be a balance between theory and practical exercises. As it is hoped that several of the specialists can teach in the training courses for technicians, emphasis should be placed on teaching methods. The course should include the remote-sensing concept, aerial photography methods, basic photogrammetry, photo-interpretation, satellite imagery and image analysis, image interpretation and mapping from satellite imagery, presentation of the results of photo-interpretation and image analysis, comparisons of classical and satellite methods, and the economics of remote sensing.

36. The course for technicians should be a simplified variant of the one for specialists customized to meet practical requirements. These courses might be organized as follows:

Managers: One- or two-day seminar given once a year.

Specialists: Three-week course. A certain amount of customization will be carried out to meet specific sector interests.

Technicians: Two-week course with staff mainly recruited from the specialist group.

Apart from these three types of course, on-the-job training should also be emphasized.

D. Remote-sensing satellite systems

1. Landsat system

37. Data and images from the Landsat system have been available since 1972. The result has been that most areas of the world are now well covered, with several images taken over the same areas at different times of year. This repeated, or multitemporal, coverage is one of the important advantages of the system as it will permit early detection and monitoring of potential environmental hazards as well as season-dependent changes in farming, natural vegetation etc.

38. Another characteristic of great importance, compared to conventional aerial photography, is the multispectral capabilities of the sensor systems on board the satellite. Instead of being limited to acquiring images of the scene in the visible and near infrared region of the electromagnetic (EM) spectrum, as with camera and film, the Landsat multispectral system records images from several bands of the visual, near and thermal infrared regions. Analysis of an image obtained in a specific part of the spectrum, or combinations from two or more bands (images), can help to differentiate between terrain features and details, which otherwise would be difficult to separate. The wavelength band intervals for two of the Landsat sensor systems, the Multi-Spectral Scanner (MSS) and TM, are indicated in the table below. The spatial resolution of the images obtained by the MSS sensor is 80 metres, while the resolution of the TM sensor is 30 metres.

Wavebands for Landsat and SPOT detectors

	Landsat		SPOT	
Band No.	MSS	TM	SX	P
1	0.5-0.6	0.45-0.52	0.50-0.59	0.51-0.73
2	0.6-0.7	0.52-0.60	0.62-0.68	
3	0.7-0.8	0.63-0.69	0.79-0.89	
4	0.8-1.1	0.76-0.90		
5		1.55-1.75		
6		10.4-12.5		
7		2.08-2.55		

2. SPOT system

39. The SPOT satellite system is in many aspects similar to the Landsat system. It has similar multispectral and multitemporal characteristics as well as the potential of large-area coverage.

40. A notable difference is the capability of SPOT to provide images of the same area obtained from consecutive orbits. While Landsat only gives a flat representation of the land surface directly below the satellite, SPOT can be programmed to view the same area during its next three orbits. This allows the construction of a quasi-stereoscopic image that can be utilized for topographic mapping. Recent studies

indicate that it is possible to produce topographic ortho-photo maps to the scales of 1:50,000 and larger, with contour intervals of 20 metres, by direct measurements based on the digital-image data.

41. Images of the Earth are obtained by SPOT with a resolution of 20 metres in its multispectral mode and 10 metres in its panchromatic mode. However, the higher resolution of the SPOT system leads to an increase of up to nine times in the number of picture elements to be handled per unit. To be able to handle all these data, the size of the scene has been reduced to approximately one tenth of that of the Landsat MSS scene, or 3,600 km^2. More SPOT images will be required to cover the same area as that covered by Landsat and the cost will be higher.

3. Landsat standard products

42. Overview images, also called "quick-looks", can be ordered as small-scale paper prints from Landsat images to check cloud cover and to identify geographical location. Quick-looks are MSS products but cover the same areas as the simultaneously obtained TM images.

43. Full-resolution images can be ordered as paper or film print in black-and-white or in colour. The spectral bands can be chosen for specific purposes and can be combined in a colour composite. Due to the increased number of pixels in the corresponding TM images, TM photography products are processed only in quarter-image scenes. The most common scale of the MSS film originals is 1:1,000,000, while for TM film products it is 1:500,000 (quarter scene).

44. MSS and TM data in digital form are delivered as full scenes with all spectral bands or a single spectral band. TM data can also be ordered covering only a quarter of the full MSS scene. Data are delivered either in raw form or corrected for radiometrical variations and geometrical distortions.

4. Standard SPOT products

45. Standard SPOT products comprise entire scenes or parts of scenes. A scene corresponds to a terrestrial area with a length of 60-80 km and a width of 60 km, depending on whether the image is obtained vertically or looking to the side. The scenes are identified on a predetermined grid on the Earth's surface and with latitude and longitude.

46. Standard products can be ordered at three levels of processing:

Level 1A. This is basically raw (unprocessed) data. Information from the detectors has been processed to normalize each spectral band. Coefficients for calibration between bands and absolute values are specified. No geometrical correction is included. The instrument's viewing angle is specified. This level of processing is particularly suitable for basic radiometric studies and stereo projections;

Level 1B. The data have been corrected for systematic errors with regard to radiometry and geometry, and to account for the Earth's rotation and curvature and angle of registration;

Level 2. A geometrically precision-corrected product. In addition to the radiometric correction in level 1B, the image has been corrected on the basis of maps or ground-control points and presented in an optional cartographic projection. Processing is done without a digital terrain model. This means that for areas with a relatively low relief and almost vertical view angles, a positional accuracy of 5 metres can be achieved in the case of panchromatic images and 10 metres for multispectral images.

5. Special SPOT products

47. In addition to the above-mentioned standard products, a number of special products are either currently available or will be in the near future, including:

Merged multispectral and panchromatic data
Scene-shifted image along the satellite track
Mosaic from two adjacent scenes along the satellite track
Mosaic from four adjacent scenes
Quarter-scene film products
Large format film products
Stereoscopic pairs
Digital terrain models extracted from SPOT stereoscopic pairs
"Level 2" geometric geocoding using ground-control points and digital terrain models to remove local distortions.

48. SPOT images are particularly advantageous in erosion studies due to its superior geometric resolution and its stereo capability. SPOT panchromatic images give terrain details, while the multispectral images give information on land use, land cover and soil type. SPOT stereo pairs give topographic information. All this is essential for the assessment of soil erosion status and soil erodability.

E. Visual interpretation of images

49. Photographic images are the cheapest and most readily available remote-sensing data. They may be acquired directly by cameras mounted on aircrafts or satellites, or produced from digital image data. Images in this form, either black and white or colour, are available for all parts of the EM spectrum accessible to remote-sensing systems.

50. Single photographs can be interpreted in two dimensions; indeed, for Landsat images, this is the only option except for small overlaps between adjacent paths. However, stereoptic viewing of overlapping photographs adds the extra dimension of relief, usually exaggerated. As well as showing topography, stereoptic viewing permits the measurement of differences in altitude and the calculation of slope angles. These factors are of great importance, both in highlighting geological features and in enabling field sites and traverses to be located accurately.

51. Interpretation of photographs for any purpose relies on several basic characteristics of the surface. These are tone, texture, pattern, shape, context and scale. These are all qualitative attributes and their use is very much a matter of experience and personal bias.

52. Aerial photographs contain a detailed record of features on the ground at the time of exposure. A photo-interpreter systematically examines the photographs and, frequently, other supporting materials such as maps and reports of field observations. Based on this study, an interpretation is made as to the physical nature of objects appearing in the photographs. Success in photo-interpretation varies with the training and experience of the interpreter, the nature of the objects being interpreted and the quality of the photographs being utilized. Generally, the most capable photo-interpreters have keen powers of observation coupled with imagination and a great deal of patience.

53. A systematic study of aerial photographs usually involves several basic characteristics of the features shown on a photograph. The exact characteristics useful for any specific task, and the manner in which they are considered, depend on the field of application.

54. At the time of the introduction of the Landsat system the expectations for practical applications, particularly in the developing countries, were quite high. The monitoring of environmental changes and inventories of natural resources in areas lacking the conventional monitoring systems of the industrialized world (i.e. ground-based systems, aircraft remote-sensing systems) was one of many important tasks to fulfil in order to cope with increased demands on the land.

55. The rather low resolution of the first image products and the vast amounts of data, however, favoured the development of computer-based data-analysis systems. When such systems were first introduced in the developing countries, their use was based on overseas technical and human resources, while local knowledge and competence concerning the land and its resources were in most cases unused. The many studies to date have been conducted by foreign experts without a concomitant education of local experts of the principles on which the technology is based. Once the foreign experts left, the training experience acquired had a limited influence on new practical applications and on the development process. There has been also an overestimation of the use of computer-assisted remote-sensing techniques and the lack of applicable results has to some extent led to a disappointment among local experts.

56. In many cases, visual interpretation of satellite images, with a knowledge of the physical process that led to them, may prove to be a preferable alternative to numerical analyses, especially in developing countries. The involvement of local expertise as well as the application of the results will be easier to achieve. The introduction of the SPOT satellite system, with a much higher resolution and the possibilities of stereo viewing, will further this approach.

57. One advantage of visual interpretation is that the same equipment can be used for conventional interpretation and mapping from aerial photographs. All developing countries have such facilities and, more important, competent staff with a good knowledge of local conditions. By contrast, many of the computer-based studies rely upon foreign equipment and foreign experts.

58. A practical application of the visual interpretation of satellite images has evolved in the developing countries because of their urgent need for rapid access to actual data for assessment of land and water resources. In most cases visual interpretation of Landsat and SPOT imagery has been based either on black-and-white images of the various spectral bands or on false colour composites (FCC). Bitemporal or multitemporal analyses are often made in order to improve the classification of the various landscape elements or monitor the annual or seasonal changes.

F. Land-use planning and environmental monitoring

59. Space-borne remote-sensing data are a very important source for land-use planning and environmental monitoring. These data are suitable for applications on the local or regional level and also for national or global investigations. Of special interest for monitoring applications is the possibility of collecting information over large areas in a short time and of repeating the data collection at regular intervals.

60. Most of the applications in this area often have in common the need to map current conditions, natural or produced by man, to use this information to manage the natural resources of a country or region properly and to monitor the environment to avoid or reduce undesirable effects on the environment and on a country's resources.

61. Image interpretation as well as digital image processing techniques are suitable tools for the evaluation of remote-sensing data for land-use planning and environmental monitoring. The purpose and goals of a specific investigation or application problem and the available resources determine how these evaluation techniques can be used. The proper selection of appropriate data types and dates for the image collection are crucial for success in individual applications.

62. For land-use planning activities high resolution space-borne data, SPOT or the Thematic Mapper for example, provide an excellent data source that often gives more recent information on local or regional conditions than existing maps. Conversely, weather satellite data and routinely derived products, such as vegetation index maps over Africa for a 10-day or one-month period, can be suitable for national or continental monitoring of the environment, for example, of vegetation development.

G. Land-use and vegetation mapping

63. Land use, land cover or vegetation maps provide important information on the current extent of different land uses or land covers. With remote-sensing data, at least major vegetation types and other land cover, such as bare soils, water or built-up areas, can be identified. In most cases, it is possible to deduce from the land cover and its spatial distribution specific land uses, for example agricultural or residential areas. Other land uses, for example, a national park, cannot be determined in remote-sensing data without additional information.

64. For many applications, land-cover or land-use maps do not require the same level of detail as used in agricultural or forest applications. Therefore, it is often easier to produce a useful land-cover or land-use map of a given area and often it requires less knowledge of local conditions than a detailed map of agricultural crops. Standard image-interpretation techniques are very efficient for identification and mapping of all major land-use classes. Interpretation experience from areas with similar natural conditions can reduce to a minimum the need for field checks.

65. In a typical colour infrared image, densely forested areas appear in different shades of dark red and brown, water in shades of blue, agricultural areas with lush green vegetation in shades of red and bare soils shading from blue to white. Field patterns can often be identified and provide indirect information on farm sizes and agricultural practices. Larger roads and railroads can often be identified and the distribution and development of more densely populated settlements are visible. Major topographical features such as valleys, plains and mountain ranges can be identified. Often it is possible to map and identify additional features and land properties, important for land-use planning, such as areas unsuitable for agriculture due to poor soils, excessive sloping or risk of flooding.

66. With high resolution, panchromatic SPOT data and derived maps can be used in a wide variety of ways, for example, to map within a city the road pattern, settlement types and areas, industrial areas (and sometimes even the type) and important natural conditions such as rivers, valleys or the land-cover and land-use pattern. This information can then be used to decide in which areas further settlement activities would be acceptable, which areas should be reserved for agricultural use and which natural conditions would favour or limit development.

67. In rural surroundings, typical land-cover information might outline densely forested hilly areas or plateaux, plains or river valleys with agriculture or grasslands. Often typical patterns in the distribution of different agricultural usages emerge, indicating natural limitations or favoured areas. Often these data also outline drastic differences in the state of the vegetation cover, indicating differences in agricultural practices or pressures on the land, which often result in serious degradation of the natural conditions due to over-exploitation. This information can be used to decide on necessary or possible changes in land use and to reduce negative effects of current land use.

H. Monitoring change

68. Land use, vegetation cover and other natural conditions are not static and change with the seasons or over long periods. These changes are of interest, for example, in the follow-up of planning decisions or in verifying the efficiency of protection measures.

69. In monitoring changes it is essential that the observed differences between two images or data sets are really due to a type of change on the ground that should be monitored and that they are not produced by other effects, such as data-collection conditions. Two images of the same location, one taken during the dry season, the other near the end of the rainy season, for example, typically differ drastically in their appearance, mainly due to differences in the vegetation development and the distribution of agricultural crops. For the mapping of crop types or the monitoring of the seasonal development of vegetation, this type of information could be of great relevance. Used for monitoring the efficiency of erosion-control measures or the extent of erosion, it could result in very serious misinterpretation.

70. The use of sequences of remote-sensing data to monitor urban development or large-scale clearcutting of forests is comparatively easy and reliable. The differences between two images in these areas are typically very large and have characteristic patterns, of roads for example, that facilitate the separation of induced from natural changes. Problems occur if the affected areas are comparatively small or the change is only gradual.

71. The situation is much more critical if only small colour changes between the images are used to obtain change information. Minor differences in the weather situation during data collection, slight delays in vegetation development and the side effects of standard processing routines can result in colour differences between two scenes, even if they are taken about the same time in different years. Therefore, results based mainly on colour changes at the same time of day but on different dates, without other clear indications in the image, should be checked very carefully to avoid misinterpretation.

I. Water-resources development and environmental monitoring

72. Remote-sensing data can be used in many ways for the development and efficient use of available water resources, which are crucial in many countries. Specific water resources, groundwater for example, can often only be indirectly mapped by remote sensing. But remote-sensing data provide many clues for the assessment of water resources, even if direct measurements are only possible in a few cases.

73. Drainage systems, catchment areas and the extent of water in major rivers and lakes can be determined from satellite data. Interpretation of types of vegetation and soil provides clues to the water available to plants, infiltration of water into the ground and expected surface run-off. In combination with weather data, this allows at least an estimate of areas with sufficient availability of water for use for different types of agriculture or grasslands. Furthermore, this information can be used to estimate the expected surface run-off and its seasonal variation within catchment areas to provide essential information for the planning of reservoirs and dams for irrigation and the production of electricity.

74. Satellite data can also be used to judge the extent and possible rate of soil erosion. Methods for a more quantitative determination of surface run-off, erosion and sedimentation rates, using remote-sensing data, are under development. Attempts within the Artemis project of the Food and Agriculture Organization of the United Nations (FAO) to estimate precipitation in Africa based on polar orbiting weather satellite data should provide interesting information on a 10-day and one-month basis. Within this project, vegetation index maps for Africa with the same time intervals are also produced.

75. High resolution data from SPOT or the Thematic Mapper can also be used to map erosion-affected or erosion-prone areas. Typically, this requires familiarity with general regional conditions and erosion processes. Additional information might be useful to differentiate various types of erosion-affected areas.

J. Sources of radar data for remote sensing

76. Launched in July 1991, ERS-1 is a low-orbit Earth observation satellite with several microwave sensors on board. The primary mission of ERS-1 is to increase the understanding of ocean processes, to monitor the

polar regions and to contribute to the World Climatology Research Programme. However, land-oriented applications will increase as the international research community gains access to the data. The primary instrument on board ERS-1 is the Active Microwave Instrument (AMI), which can provide high-resolution images (C-band), wind speed through ocean-wave spectra analyses and the length and direction of ocean waves. Operating in the imaging mode, AMI covers a swath of 80-100 km, with an initially assessed resolution of 27 metres in range and 29 metres in azimuth.

77. Since the launch in July 1991, the ERS-1 satellite has acquired over 400,000 radar scenes. Of these, some 10,000-15,000 have been processed. In environmental applications, the all-weather advantages of ERS-1 synthetic aperture radar (SAR) for tropical, high-rainfall and equatorial regions were well to the fore.

78. The use of radar imagery in planning is still at the methods investigation stage. Problems still to be solved include the need to develop geometrical modelling, geocoding tools, mosaicking and fusion, reducing the distortion effects of relief and smoothing out speckle.

79. In the image-processing area, there is a need for dedicated tools for processing radar imagery. If segmentation based solely on ERS-1 SAR imagery fails, a radar image can be segmented using SPOT data with a cloud cover of up to 50 per cent.

80. ERS-1 SAR data are particularly useful for coverage of a large area but less so for a small area. For studying non-renewable resources, the spectral wealth of SPOT data complement the ERS-1 data as regards texture and the interpretation of morphology, particularly in areas of low relief. However, certain phenomena continue to pose interpretation problems.

81. For renewable resources, ERS-1 data combined with optical data provide more information than was anticipated. In agriculture, projects are in progress to incorporate ERS-1 data into a number of programmes. The results obtained so far demonstrate the usefulness and complementarity of radar data for discriminating and monitoring different crops. In the same way, ERS-1 data provide coverage of certain areas of tropical forest in the Amazon region, making it possible to locate and monitor deforestation.

II. COURSE EVALUATION

82. At the conclusion of the course, the participants were asked to complete a questionnaire regarding various aspects of the content and organization of the course, including the time allotted to the topics and practical exercises as well as the relevance of the course content for their day-to-day activities. That exercise was followed by a discussion of problems of remote-sensing education in developing countries. During the discussions, the participants made a number of observations on the accomplishments of the course and recommendations for future courses.

83. All participants expressed the opinion that the general organization and planning of the presentations were of high quality. Depending on their experience and field of expertise, some participants felt that more time should have been spent on topics related to Geographic Information Systems and remote-sensing education. All the participants were of the view that the level and conduct of the course were appropriate for the specific needs of their educational and academic work.

Annex

PROGRAMME OF THE COURSE

I. INTRODUCTION

Date	Subject	Speaker
Monday 3 May	Introductory lectures:	
	Centre for Space Science and Technology Education - A United Nations Initiative	A. Abiodun
	Remote sensing and global change	
	Management of natural resources and the environment - the role of remote sensing	P. Williamson M. Byström
	Presentation of the Department of Physical Geography - education and research	W. Karlén C. Christiansson B. Lundén

II. FUNDAMENTAL PRINCIPLES

Tuesday 4 May	Electromagnetic radiation, the reflective properties of the earth and elementary optics	J. Kleman
	Electromagnetic radiation, the reflective properties of the earth and elementary optics (continued)	J. Kleman
Wednesday 5 May	Electronic imaging	F. Quiel
	Electronic imaging (continued)	F. Quiel
	Visit to the Stockholm University Information Unit and the International Affairs Unit at the main university campus	
Thursday 6 May	Modern cartography in thematic mapping	M. Buchroithner
Friday 7 May	Earth resources and environmental satellites	M. Buchroithner
	Image interpretation - theory	G. Alm
Monday 10 May	The new generation of environmental satellites - the case of ERS-1	J. Lichtenegger

III. IMAGE INTERPRETATION

Monday 10 May	Lectures on the use of imagery for:	
	(a) Land-use planning and environmental monitoring	F. Quiel
	(b) Geological studies	B. Lundén
Tuesday 11 May	Case-studies for African, Asian and Latin American participants respectively in groups of nine	
Wednesday 12 May	Case-studies	
	AFRICA	
	Land degradation and soils in Lesotho	B. Lundén
	Land and water development in Ethiopia	R. Å. Larsson
	Land forms and land degradation in semi-arid Tanzania	A. Yrgård
	ASIA	
	Land degradation and soils in Lesotho	B. Lundén
	Environmental impact assessment of the closure of a river arm in Bangladesh	R. Å. Larsson J. Nisell
	LATIN AMERICA	
	Forestry in Ecuador	R. Å. Larsson
	Geological applications from Central America	R. Lilljequist
	Land degradation and soils in Lesotho	B. Lundén

IV. DIGITAL IMAGE PROCESSING AND ANALYSIS/GIS

Thursday 13 May	Digital analysis (theory)	W. Arnberg
	Computer enhancement (theory)	W. Arnberg
Friday 14 May	Geographical Information Systems (GIS) (theory)	F. Quiel
	GIS (theory) (continued)	F. Quiel
Monday 17 May	Computer-aided analysis	B. Lundén
	Computer-aided analysis (continued)	B. Lundén
Tuesday 18 May	GIS exercise	B. Lundén
	GIS exercise (continued)	B. Lundén

V. REMOTE-SENSING EDUCATION AND PROJECT MANAGEMENT

Wednesday 19 May	In-service training in remote sensing in the third world	R. Å. Larsson
	Project management - theoretical background and brief role-play exercise	J. Valdelin
	Project management (continued)	J. Valdelin

VI. REMOTE-SENSING APPLICATIONS

Monday 24 May	Introduction to the Kiruna part of the course	R. Bergström
	Preparation for field excursion	
	Field excursion. Demonstrations of image material, study of landscape feature interpretation in satellite imagery	R. Å. Larsson M. Orrmalm R. Bergström
	Presentation of Abisko Scientific Research Station and current research at the station	
Tuesday 25 May	Field work exercise. Image interpretation in groups	R. Å. Larsson M. Orrmalm R. Bergström
Wednesday 26 May	Group presentations of the field work	R. Å. Larsson
	Presentation of ESA/ESR-1 Ground segment	B. Eriksson
	Departure to Jukkasjärvi from where trip to Salmijärvi and Esrange satellite stations	
	Study visit to ESA Salmijärvi Satellite Station	
	Study visit to Esrange Satellite Station	
Thursday 27 May	Basic processing: Archiving, catalogue updating, standard production	J. Unga
	Image processing, value-added production, radiometric and geometric corrections, digital elevation model and digital terrain model extraction, ortho-image production	T. Westin
	Computerized cartography, production system	M. Dahlberg
	Study visit to Satellitbild production facilities; station-wise presentations	

Friday 28 May	Visual interpretation of satellite images, use of imagery in project planning	M. Byström H. Rasch R. Bergström
	Visual interpretation of satellite imagery (continued)	M. Byström H. Rasch R. Bergström
Saturday 29 May	Visual interpretation of satellite imagery (continued)	M. Byström
	Visual interpretation of satellite imagery (continued)	M. Byström
Monday 31 May	Visual interpretation of satellite imagery (continued)	M. Byström
Tuesday 1 June	Group presentations of results of visual interpretation and project planning	M. Byström
	Group presentations of results of visual interpretation and project planning (continued)	M. Byström

VII. NEEDS OF THE USER

Wednesday 2 June	Landsat and SPOT satellites	R. Bergström
	Standard and refined processed images	G. Rönnbäck
	Photographic end products	S. Forslund
	Use of enhanced images; different media; choosing the right media and products	R. Bergström
	Ordering Satellite Data	J. Ek
	Demonstrations: Customer Services Dept.	
	SSC projects and products	A. E. Öskog
	Presentation of two current projects:	
	(1) Land cover mapping in Malawi	U. Malmberg
	(2) A mapping project in Malaysia	H. Rasch
Thursday 3 June	Seminar: Future trends in remote sensing	S. W. Bie
	Closure of Section VI and VII	

VIII. SUMMARY AND EVALUATION

Friday 4 June	Swedish foreign aid	S. Pettersson
	Course evaluation	W. Arnberg R. Bergström R. Å. Larsson B. Lundén S. Pettersson, F. Quiel L. Wastenson